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(54) A parallax barrier assembly and apparatus

(57) A parallax barrier assembly includes two substantially equally spaced apart, overlying, semi-light transparent, sheet-like members (10) each providing or being provided with, an array of closely spaced, substantially parallel, light-opaque, narrow width strips (11). The spacing and width of the strips (11) is such that when the members (10) are located substantially vertically transverse to and in front of a viewer (3, 4) with the strips (11) extending substantially vertically, the strips (11) cooperate to provide a visual indication to the view of an optimum viewing position of the viewer (3, 4) relative to the assembly. Preferably the assembly includes part of apparatus for autostereoscopic display in which a sheet-like composite image to be displayed (1) made up of interleaved left eye and right eye stereo sub-images arranged in narrow, substantially vertical, substantially parallel, columns (p) is located either between the two members (10) or behind two members (10).

Fig. 4.

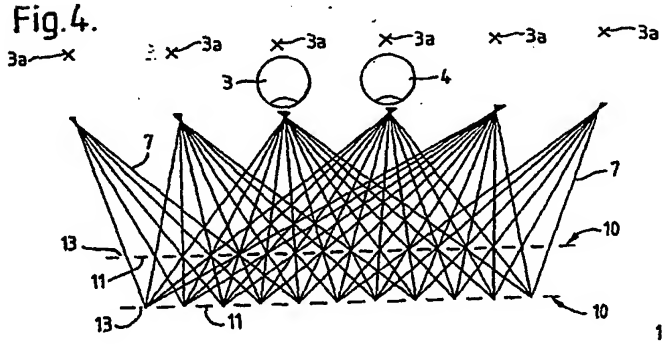
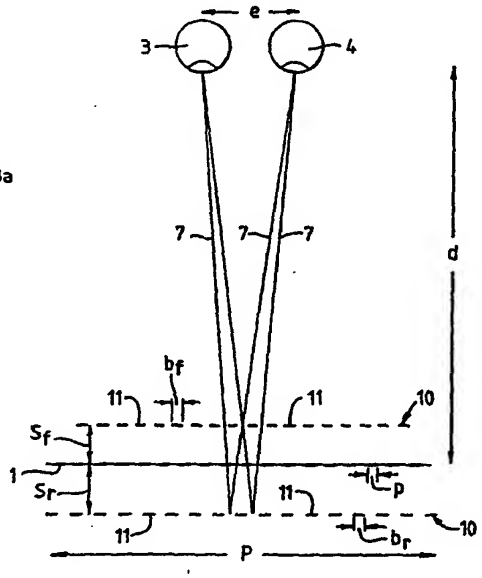


Fig. 6.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

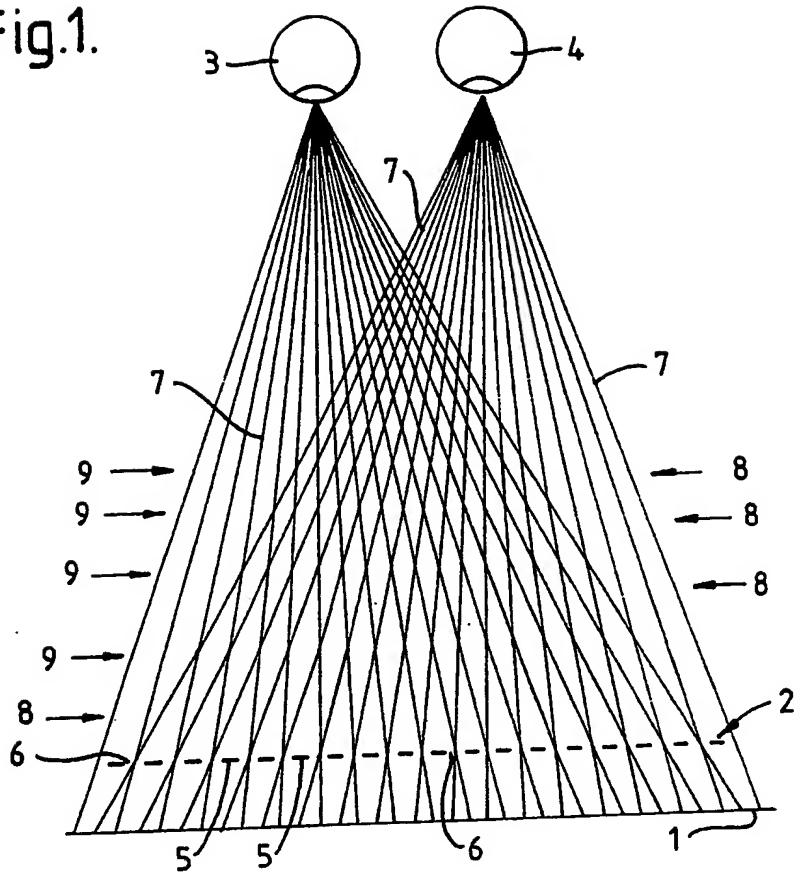

Fig.2.

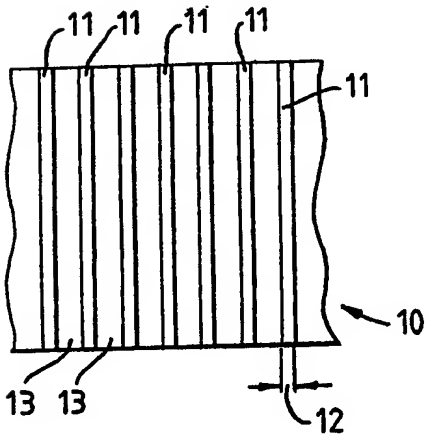

Fig.3.

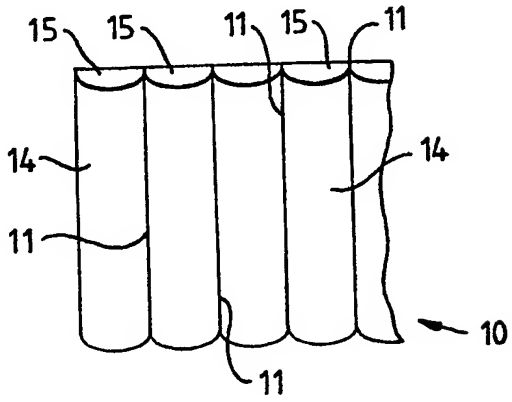

Fig.4.

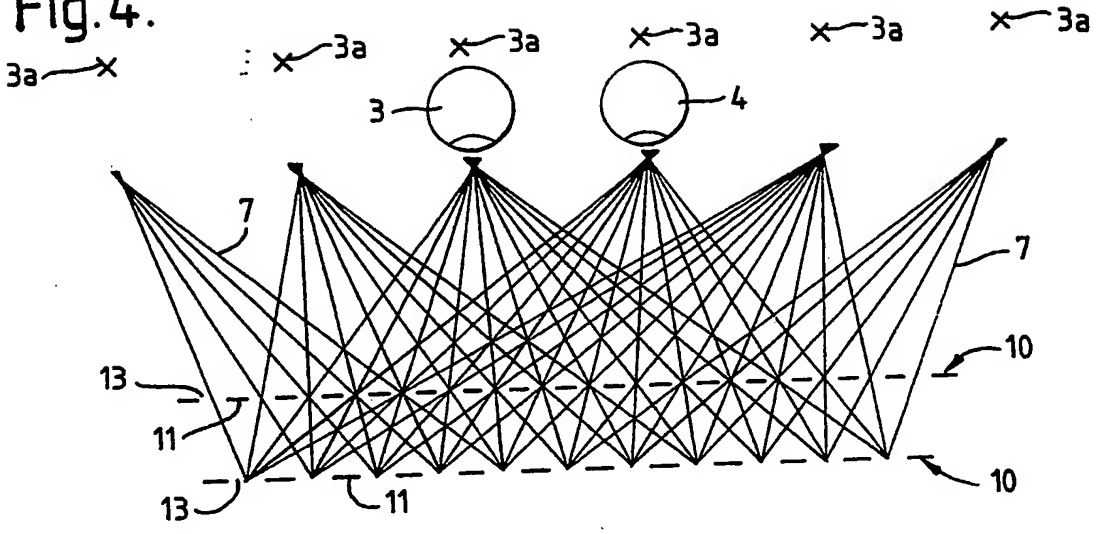
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Fig.5.

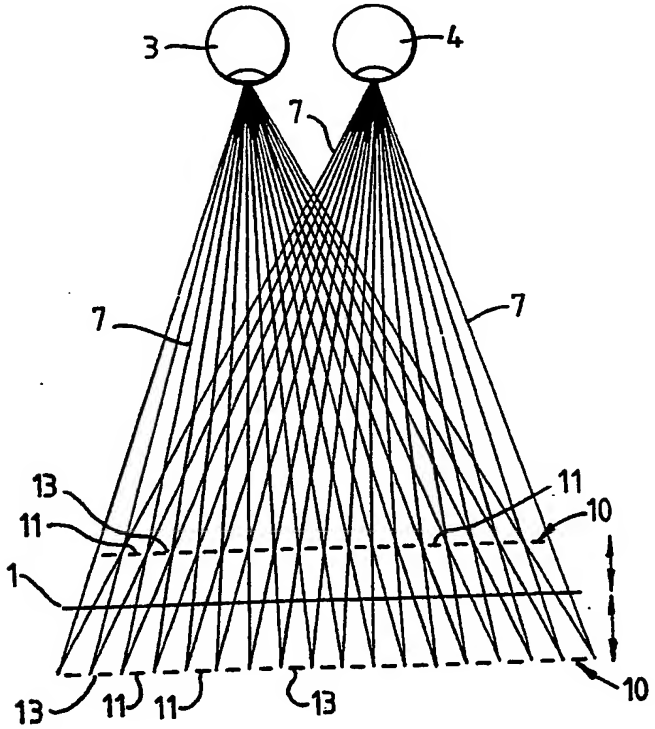
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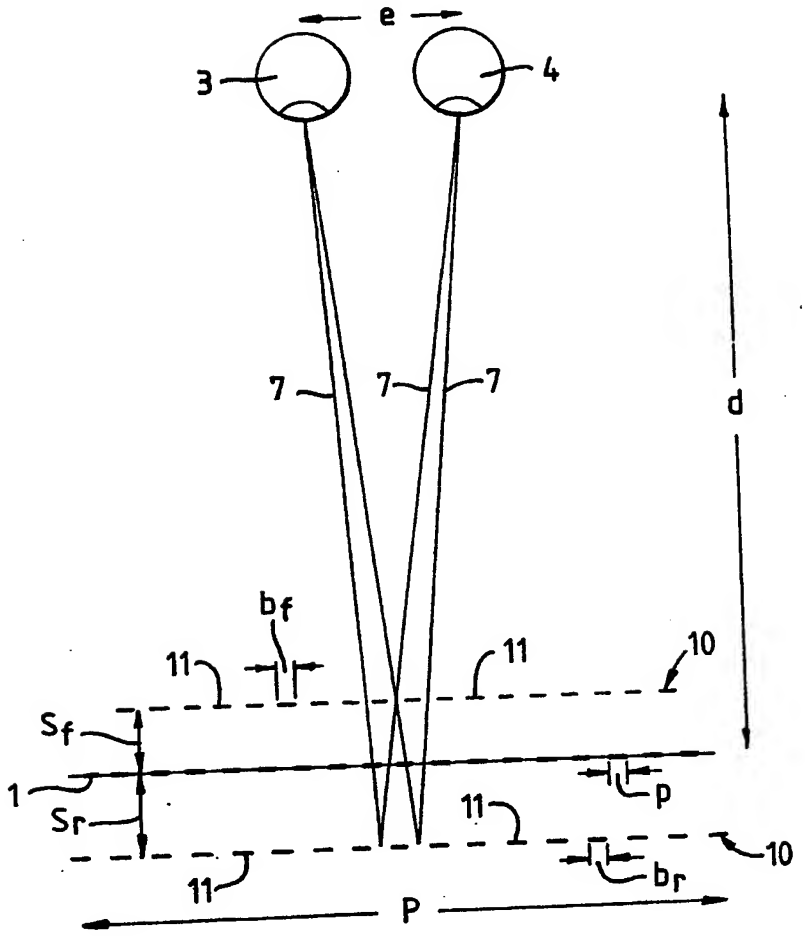
Fig. 6.



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A PARALLAX BARRIER ASSEMBLY AND APPARATUS

This invention relates to a parallax barrier assembly, particularly, but not exclusively, suitable for providing a visual indication of an optimum viewing position and to apparatus for autostereoscopic display incorporating such an assembly.

One of the problems with known methods of autostereoscopic displays, which are stereoscopic displays which do not require special viewing glasses or other viewing apparatus, is to provide the left and right eye stereo images to the correct eyes without interference taking place between the two images and thus creating either a non-stereoscopic display to the viewer, a poorly resolved display image or no display image at all. One known method of autostereoscopic display involves interleaving the left and right stereo images in narrow substantially vertical columns side by side in sheet like form and to overlay the compound image or sheet like picture thereby formed with a parallax barrier, preferably in the form of a grating, which is mounted between the viewer and the compound image picture close to and spaced therefrom. The grating is made up of opaque strips in substantially parallel spaced apart array, which strips are slightly narrower in width than the width of the columns in the compound image picture. The grating is arranged so that each eye sees only alternate columns in the image and this is used to direct the appropriate image to the appropriate eye.

This known method of autostereoscopic display utilising a single parallax barrier or grating between the viewer and the compound image plane allows an image to be seen by a viewer from an infinite number of positions as shown in the accompanying Figure 1. Only at certain positions, where the parallax barrier is seen aligned with the vertical columns of the image, is a three-dimensional perception of the image obtainable. The viewer thus has the problem of how to position himself or herself for an optimum viewing position where a three-dimensional perception is obtainable.

There is thus a need for a generally improved parallax barrier assembly able to provide a viewer with an optimum viewing position and for a generally improved autostereoscopic display apparatus, using such an assembly, which is capable of affording the viewer a relatively easy way of determining one or more optimum viewing positions in which a three-dimensional perception is obtainable.

According to a first aspect of the present invention there is provided a parallax barrier assembly, including at least two substantially equally spaced apart, overlying, semi-light transparent, sheet-like members each providing, or being provided with an array of closely spaced, substantially parallel, light-opaque, narrow width strips, with the spacing and width of the strips being such that when the members are located substantially vertically transverse to and in front of a viewer, with the strips extending substantially vertically, the strips

cooperate to provide a visual indication to the viewer of an optimum viewing position of the viewer relative to the assembly.

Preferably the sheet-like members are substantially parallel to one another.

Conveniently each sheet-like member is in the form of a grating made up of a sheet of light transparent material carrying or including the array of light opaque strips.

Alternatively one of said sheet-like members, which is rear most with respect to a viewer, is in the form of a grating made up of a sheet of transparent material carrying or including one array of light-opaque strips and the other of said sheet-like members, which is foremost with respect to a viewer, is in the form of a lenticular screen made up of a series of semi-cylindrical light transparent lenses arranged in side-by-side contact so that their flat bases form a rear face for the screen and the lines of contact between adjoining lens form said opaque strips.

As a further alternative each sheet-like member may be in the form of a lenticular screen made up of a series of semi-cylindrical light transparent lenses arranged in side-by-side contact so that their flat bases form a rear face for the screen and the lines of contact between adjoining lenses form said opaque strips.

Preferably the spatial frequency of the sheet-like member nearmost, in operation, to a viewer is coarser than the furthermost sheet-like member, so that, in operation, the viewer

sees the spatial frequencies of the members to be substantially the same.

According to a further aspect of the present invention there is provided apparatus for autostereoscopic display, including a parallax barrier assembly as hereinbefore described and, located between, or behind with respect to a viewer, the at least two sheet like members, a sheet-like composite image to be displayed made up of interleaved left eye and right eye stereo sub-images arranged in narrow, substantially vertical, substantially parallel, columns, with the arrangement being such that the sheet-like members cooperate with the sheet-like composite image to present a stereo image to a viewer in one or more optimum viewing positions but interfere and effectively extinguish the image when the viewer is displaced from said one or more optimum viewing positions.

Preferably the apparatus includes a source of diffuse light located behind the rear most sheet-like member with respect to a viewer.

Alternatively the apparatus includes a source of collimated light located behind the rear most sheet-like member with respect to a viewer.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a diagrammatic view of the possible light ray paths for a conventional parallax barrier assembly, not according

sees the spatial frequencies of the members to be substantially the same.

According to a further aspect of the present invention there is provided apparatus for autostereoscopic display, including a parallax barrier assembly as hereinbefore described and, located between, or behind with respect to a viewer, the at least two sheet like members, a sheet-like composite image to be displayed made up of interleaved left eye and right eye stereo sub-images arranged in narrow, substantially vertical, substantially parallel, columns, with the arrangement being such that the sheet-like members cooperate with the sheet-like composite image to present a stereo image to a viewer in one or more optimum viewing positions but interfere and effectively extinguish the image when the viewer is displaced from said one or more optimum viewing positions.

Preferably the apparatus includes a source of diffuse light located behind the rear most sheet-like member with respect to a viewer.

Alternatively the apparatus includes a source of collimated light located behind the rear most sheet-like member with respect to a viewer.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a diagrammatic view of the possible light ray paths for a conventional parallax barrier assembly, not according

to the invention, having a single barrier located between a viewer and an interleaved compound stereo image,

Figure 2 is a plan view of a detail of one form of grating or barrier for use with an assembly and apparatus according to the present invention,

Figure 3 is a perspective view of a detail of an alternative form of grating or barrier for use with the assembly and apparatus of the present invention,

Figure 4 is a diagrammatic view of the possible light paths for a parallax barrier assembly according to the present invention, which does not have a compound stereo image plane or sheet, showing optimum viewing positions,

Figure 5 is a view similar to that of Figure 1, of the possible light ray paths for a parallax barrier assembly according to another aspect of the present invention, and

Figure 6 is a schematic simplified light ray diagram for the assembly of Figure 5 forming the basis for a mathematical analysis.

Figure 1 of the accompanying drawings shows in diagrammatic plan view from above a conventional parallax barrier assembly, not according to the invention, in use with a compound stereo image in the form of a flat plane or sheet 1. This compound stereo image plane or sheet 1 is in the form of interleaved left eye and right eye stereo images in narrow, closely spaced, substantially vertical columns (not shown). The conventional assembly includes a parallax barrier, or grating 2

which overlays the compound stereo image plane 1 at a spacing therefrom so that the barrier 2 lies between, and substantially parallel to, the plane 1 and a viewer represented by eyes 3 and 4. Thus the compound stereo image plane 1 and barrier 2 are located transversely in front of the eyes 3 and 4 so that the columns of the stereo image extend substantially vertically with respect to the eyes.

The barrier or grating 2 is made up of an array of narrow width opaque strips 5 arranged in closely spaced array to define there between gaps 6 which are transparent to the passage of visible light. The single barrier or grating 2 is so located in front of the compound stereo image plane 1 that each eye 3 and 4 sees only alternate strips in the image so that the appropriate image is directed to the appropriate eye. From a consideration of Figure 1 it can be seen that there are a great number of possible ray paths 7 and hence a considerable number of potential locations for both the in compound stereo image plane 1 and barrier or grating 2. For example the compound stereo image plane 1 can be located at positions 8 and the barrier or grating 2 can be located at positions 9 for optimum viewing by the eyes 3 and 4 in the illustrated optimum position. As previously described such a conventional assembly provides insufficient indication to a viewer of a correct position or location for the viewer to ensure a required three-dimensional perception of the compound image. Although the image can be seen from an infinite number of positions it is only in certain positions, where the barrier or grating 2 is seen aligned with

the vertical strips of the compound stereo image plane 1 that a three-dimensional stereo perception is obtainable.

According to a basic embodiment a parallax barrier assembly of the present invention, as shown in Figure 4, includes at least two substantially equally spaced apart, overlying, semi-light transparent, sheet-like members 10, each provided, or being provided with, an array of closely spaced, substantially parallel, light-opaque, narrow width strips 11. The spacing and width of the strips 11 is such that when the members 10 are located substantially vertically transverse to and in front of a viewer, with the strips 11 extending substantially vertically, the strips 11 cooperate to provide a visual indication to the viewer of an optimum viewing position 3a of the viewer relative to the assembly. As shown in Figure 4 the members 10 are substantially parallel to one another.

Each sheet-like member 10 may be in the form of a grating as shown in Figure 2 made up of a sheet of light transparent material carrying or including the array of light opaque strips 11. Preferably such a member 10 is made of plastics sheet with light opaque strips in the form of lines provided thereon for example by a photographic technique in a photographic emulsion. Alternatively such a grating may be provided by means of laser print on plastics tape or by any other convenient form of ink or heat printing. Such a grating allows the transmission of light there through via the spacings or gaps 13 between the strips 11.

Alternatively one of the members 10, which is rearmost with respect to a viewer, is in the form of the grating of Figure 2 whilst the other member 10, which is foremost with respect to a viewer, is in the form shown in Figure 3. In Figure 3 the member 10 is in the form of a lenticular screen made up of a series of semi-cylindrical light transparent lenses 14 arranged in side-by-side contact so that their flat bases 15 form a rear face and the lines of contact between adjoining lenses 14 form the opaque strips 11.

In yet another example, each sheet-like member 10 is in the form of the lenticular screen of Figure 3. Thus a parallax barrier assembly according to the present invention functions such that in an optimum position 3a the viewer sees a uniform, grey field, or if the individual strips 11 are resolved, a uniform striped field. If the viewer is displaced towards or away from the assembly out of an optimum viewing position he only sees moiré images in stripes. If the viewer is laterally displaced from the optimum viewing position the field of view will first darken, the image if present being extinguished, and then lighten as the viewer moves beyond the midpoint between two positions 3a. The darkening effect corresponds to strips 11 of one member 10 overlying gaps 13 of the other member 10 and the lightening effect corresponds to the strips 11 of one member 10 overlying the strips 11 of the other member 10. In other words the two members 10 act to interfere and effectively extinguish an image when the viewer moves laterally from one of the optimum viewing positions. Movement towards or away from the assembly out of

an optimum viewing position initially causes broad vertical stripes to appear on the image as a result of interference between the members 10, which stripes become narrower as the viewer moves further away from an optimum viewing position.

Movement of the viewer vertically up or down out of the optimum viewing positions 3a will only affect the field of view when the distance to the nearer edge of the assembly is significantly less than that to the further edge in which case broad horizontal bounds will appear on the field.

Although six optimum viewing positions 3a are shown in Figure 4 most of these will be from such oblique viewpoints as to be impractical. Using two members 10 of different but constant spatial frequency of strips 11, the positions 3a lie in a plane parallel to the members 10 with a lateral spacing or separation determined by the spacing between the members 10 and the difference in their spatial frequency.

Whilst the parallax barrier assembly of the invention can be used, as in Figure 4, as a means of providing a position cue for the viewer a preferred use is as part of an autostereoscopic display apparatus. To this end such apparatus, as shown in Figures 5 and 6, includes a parallax barrier assembly of the present invention and, located between the at least two members 10, a sheet-like composite image 1 to be displayed, as previously described, made up of interleaved left eye and right eye stereo sub-images arranged in narrow, substantially vertical, substantially parallel, columns. Alternatively the composite image 1 can be located in front of the two members 10 with

respect to a viewer. The arrangement is such that the members 10 cooperate with the composite image plane 1 to present a stereo image to a viewer, or a number of viewers, in one or more optimum viewing positions but interfere and effectively extinguish the image, first darkening and then lightening the field of view, when the viewer is displaced laterally from an optimum viewing position. In the optimum viewing position the strips 11 in one member 10 overlie the strips 11 in the other member 10. Whilst in a conventional parallax barrier assembly as shown in Figure 1 left and right eye views of the composite image plane 1 are still directed to the wrong eye in some 50 per cent of the locations, this is not the case in the apparatus of Figures 4, 5 and 6 according to the present invention. In the case of a transmissive image as shown in Figure 5, one member 10 may be in front of and the other behind the composite image plane 1. However with an emissive display both members 10 could be in front of the composite image plane 1. When the members 10 are each in the form of a grating as shown in Figure 2 or where one such member is in the form of a grating of Figure 2 and the other member 10 is in the form of a lenticular screen of Figure 3, a source of diffuse light should be located behind the rear most member 10 with respect to the viewer. Alternatively where both members 10 are in the form of the lenticular screen of Figure 3 a source of collimated light should be located behind the rear most member 10 with respect to the viewer.

With the apparatus for autostereoscopic display of the present invention, as shown in Figure 5 the image alternation frequency, the grating frequencies, the spacing between the image and the members 10, and the viewing distance are all related. It is desirable to raise the image alternation and grating frequencies to a level where the grating strips 11 are not resolved (i.e. each strip subtending less than 0.5 minutes of arc at the eye). This is a similar criterion to that applied to the raster structure on CRT displays. A fine grating also requires smaller spacing between the image and the members 10, so that the assembly can be implemented in a flat, lightweight sandwich. Preferably an image alternation frequency of greater than 500 lines per picture width (again comparable with raster requirements) is required. The angles subtended by a composite image column and a grating strip 11 at the eye will, of course be equal as the aim is for the grating strip 11 to occlude the relevant composite image column. In the relationships illustrated in Figure 6

e = eye spacing (6.3-6.5 cm in adults)

d = viewing distance (eye to image)

s_f = spacing from image to nearest possible front member location.

s_r = spacing from image to nearest possible rear member location.

P = picture width

p = width of picture image column

b_f = width of front grating member strip

b_r = width of rear grating member strip

The relationships are:

1. Grating member strip width determined from viewing distance and image column width:

$$b_f = \frac{d - s}{d} \times p \quad \text{---------- (1)}$$

$$b_r = \frac{d + s}{d} \times p \quad \text{---------- (2)}$$

i.e. the grating strip width is in proportion to its distance from the eye so that the subtended angle is the same as that of the picture image column.

2. Image/Grating Spacing determined from same parameters;

$$s_f = \frac{p \times d}{e + p} \quad \text{---------- (3)}$$

$$s_r = \frac{p \times d}{e - p} \quad \text{---------- (4)}$$

The thickness of a flat panel display constructed in this way would be $s_f + s_r$

In practice, although it would be desirable to determine the member 10 and spacing parameters from given image characteristics and viewing distance as above, it is equally possible to determine the required viewing distance if grating subtense and spacing cannot be manipulated to an exact specification.

An example of practical realistic figures is:

Picture image column width; 0.338mm (512 lines per 17.5cm picture width).

Viewing distance; 750mm.

It therefore follows that:

$b_f = 0.9894 \times p$, (0.99 will suffice, depending on the number of picture elements, but 1.00 will not).

$s_f = 4mm.$

The foregoing assembly and apparatus of the present invention can be used with flat panel displays to make a simple form of three-dimensional T.V. practical with existing display

technology. For example the assembly and apparatus may b used in association with flat panel transmissive or backlit displays such as liquid crystal displays and for single user graphics work stations. The picture image columns and gratings should be sufficiently fine that the lines are not fully resolved. The spatial frequency of the members 10 should be substantially the same to the eyes of a viewer. As they are located at different distances from the eyes the furthermost member should be coarser than the nearmost member.

CLAIMS

1. A parallax barrier assembly, including at least two substantially equally spaced apart, overlying, semi-light transparent, sheet-like members each providing, or being provided with, an array of closely spaced, substantially parallel, light-opaque, narrow width strips, with the spacing and width of these strips being such that when the members are located substantially vertically transverse to and in front of a viewer, with the strips extending substantially vertically, the strips cooperate to provide a visual indication to the viewer of an optimum viewing position of the viewer relative to the assembly.

2. An assembly according to claim 1, wherein the sheet-like members are substantially parallel to one another.

3. An assembly according to claim 1 or claim 2, wherein each sheet-like member is in the form of a grating made up of a sheet of light transparent material carrying or including the array of light opaque strips.

4. An assembly according to claim 1 or claim 2, wherein the one of said sheet-like members, which is rearmost with respect to a viewer, is in the form of a grating made up of a sheet of transparent material carrying or including one array of light-opaque strips and wherein the other of said sheet-like members, which is foremost with respect to a viewer, is in the form of a lenticular screen made up of a series of semi-cylindrical light transparent lenses arranged in side by side contact so that their flat bases form a rear face for the screen,

and the lines of contact between adjoining lens form said opaque strips.

5. An assembly according to claim 1 or claim 2, wherein each sheet-like member is in the form of a lenticular screen made up of a series of semi-cylindrical light transparent lenses arranged in side-by-side contact so that their flat bases form a rear face for the screen and the lines of contact between adjoining lenses form said opaque strips.

6. A parallax barrier assembly according to anyone of claims 1 to 5, wherein the spatial frequency of the sheet-like member nearmost, in operation, to a viewer is coarser than the furthermost sheet-like member, so that, in operation, the viewer sees the spatial frequencies of the members to be substantially the same.

7. A parallax barrier assembly, substantially as hereinbefore described with reference to and as illustrated in Figure 4 or Figures 5 and 6 as modified or not by Figure 2 or Figure 3 of the accompanying drawings.

8. Apparatus for autostereoscopic display, including a parallax barrier assembly according to any one of claims 1 to 7, and, located between, or behind with respect to a viewer, the at least two sheet-like members, a sheet-like composite image to be displayed made up of interleaved left eye and right eye stereo sub-images arranged in narrow, substantially vertical, substantially parallel, columns, with the arrangement being such that the sheet-like members cooperate with the sheet-like composite image to present a stereo image to a viewer in one or more optimum viewing positions but interfere and effectively

extinguish the image when the viewer is displaced from said one or more optimum viewing positions.

9. Apparatus according to claim 8, when appended to claim 3 or Claim 4, including a source of diffuse light located behind the rearmost sheet-like member with respect to a viewer.

10. Apparatus according to claim 8 when appended to claim 5, including a source of collimated light located behind the rearmost sheet-like member with respect to a viewer.

11. Apparatus for autostereoscopic display substantially as hereinbefore described with reference to Figure 4 or Figures 5 and 6 as modified or not by Figure 2 or Figure 3 of the accompanying drawings.

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Examin r's report to th Comptroller under Section 17 (The S arch Report)

Application number 9101366.4

Rel vant Technical fields

(i) UK Cl (Edition K) G2J (JX15)

(ii) Int Cl (Edition 5) G02B

Search Examiner

D J Riddoch

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

2. March 1991

Documents considered relevant following a search in respect of claims All

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB A 2004085	BERGKIRST Figure 2	1
X	GB 1093232	cf Figure 3	1

SF2(p)

H03AAY

Category	Identity of document and rel vant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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